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**TIDAL SEEPAGE METER**2                   **BACKGROUND OF THE INVENTION**

3                 The present invention is generally in the field of seepage meters or Lee meters. Seepage  
4         meters quantify variable rates of flow and chemical transport between groundwater and surface  
5         water.

6                 Typical seepage meters can only obtain one sample per use, which increases cost and  
7         danger to divers when used to obtain multiple samples over a time period.

8                 Therefore, a need exists for seepage meters that can obtain multiple samples per use.

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2                   BRIEF DESCRIPTION OF THE DRAWINGS

3                 FIGURE 1 is a block diagram of one embodiment of the present invention.

4                 FIGURE 2 is a block diagram of one embodiment of a power supply of the present  
5 invention.6                 FIGURE 3 is an exemplary representation of implementing an embodiment of the present  
7 invention.

8                 FIGURE 4 is an exemplary embodiment of the present invention.

9                 FIGURE 5 is an exemplary selector valve and sample container embodiment of the  
10 present invention.11                FIGURE 6 is a flowchart of an exemplary method of implementing an embodiment of the  
12 present invention.13                FIGURE 7 is a flowchart of an exemplary method of implementing an embodiment of the  
14 present invention.

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1                   DETAILED DESCRIPTION OF THE INVENTION

2                 The present invention is directed to a method and apparatus for tidal seepage meters.  
3                 Although the invention is described with respect to specific embodiments, the principles of the  
4                 invention, as defined by the claims appended herein, can obviously be applied beyond the  
5                 specifically described embodiments of the invention described herein. Moreover, in the  
6                 description of the present invention, certain details have been left out in order to not obscure the  
7                 inventive aspects of the invention. The details left out are within the knowledge of a person of  
8                 ordinary skill in the art.

9                 The drawings in the present application and their accompanying detailed description are  
10          directed to merely exemplary embodiments of the invention. To maintain brevity, other  
11          embodiments of the invention that use the principles of the present invention are not specifically  
12          described in the present application and are not specifically illustrated by the present drawings.

13                 The present inventive method and apparatus for tidal seepage meters includes a power  
14          supply, controller, motor, selector valve, seepage chamber and multiple sample containers. In  
15          one embodiment, the present invention can obtain multiple samples per use.

16                 FIGURE 1 is a block diagram of one embodiment of the present invention. As shown in  
17          FIG. 1, tidal seepage meter (TSM) 100 includes power supply 110, motor relay 120, controller  
18          130, motor 140, selector valve 150, seepage chamber 160 and at least two sample containers 170.  
19          Controller 130 is operatively coupled to motor relay 120. Controller 130 inputs control signals  
20          to components such as motor relay 120. In one embodiment, controller 130 includes a circuit  
21          board with interpreter chip, EEPROM, 5-volt regulator, reset circuit and resonator. In one  
22          embodiment, controller 130 is a BASIC STAMP II® by PARALLAX INC. Controller 130  
23          controls the sampling of TSM 100 according to a sampling schedule. A sampling schedule is a  
24          time schedule that designates desired times for obtaining samples. In one embodiment, a  
25          sampling schedule obtains six total samples taken at four-hour intervals, which represents a one-  
26          day tidal cycle. In one embodiment, controller 130 obtains sampling schedules from computer  
27          190. In one embodiment, computer 190 downloads sampling schedules to controller 130 via an  
28          interface link such as six-wire cable, optical, infrared and rf links. In one embodiment, TSM 100  
29          further includes computer 190. In one embodiment, TSM 100 temporarily links to computer 190  
30          to receive sampling schedules. In one embodiment, controller 130 further includes an activation

1 signal to enable/disable a power supply (e.g., power supply 110 and battery relay control  
2 signals).

3 Power supply 110 is operatively coupled to motor relay 120. Power supply 110 can be  
4 AC or DC power supplies. Exemplary power supplies include DC batteries and AC generators.  
5 In one embodiment, power supply 110 is a 12VDC gel cell battery rated at 1.2 amp hour. Power  
6 supply 110 inputs voltage signals to motor relay 120.

7 FIGURE 2 is a block diagram of one embodiment of a power supply of the present  
8 invention. As shown in FIG. 2, power supply 210 includes DC battery 212, battery relay 214  
9 and inverter 216. In one embodiment, DC battery 212 is a 12 VDC gel battery rated at 1.2 amp  
10 hour. DC battery 212 is operatively coupled to battery relay 214. Battery relay 214 is capable of  
11 receiving control signals from a controller. In one embodiment, battery relay 214 is a solid state  
12 DC relay with a control line rated at 3.5-32 VDC, 1.6 microamps at 5 VDC. Battery relay 214 is  
13 operatively coupled to inverter 216. Inverter 216 is capable of inverting a DC signal to produce  
14 an AC signal. In one embodiment, inverter 216 converts 12 VDC to 115 VAC at 60 Hz. In one  
15 embodiment, inverter 216 provides 115 VAC at 140 watts. In one embodiment, inverter 216 is  
16 rated for 400-watt surges. Inverter 216 inputs an AC signal to a motor relay.

17 Referring again to FIG. 1, motor relay 120 is operatively coupled to power supply 110,  
18 controller 130 and motor 140. Motor relay 120 is capable of receiving control signals from  
19 controller 130. In one embodiment, motor relay 120 is a solid state AC relay with a control line  
20 rated at 3-32 VDC, 3.4 microamps at 5 VDC. Motor relay 120 operatively couples power supply  
21 110 and motor 140 when activated by control signals from controller 130, which is in accordance  
22 with a sampling schedule.

23 Motor 140 is operatively coupled to motor relay 120 and selector valve 150. Motor 140  
24 receives voltage signals from power supply 110 via motor relay 120 in accordance with a  
25 sampling schedule. Exemplary motors include stepper motors, hydraulics and spring-driven  
26 mechanisms. In one embodiment, motor 140 is an AC motor. In one embodiment, motor 140 is  
27 a DC motor. In one embodiment, motor 140 is a 90-degree stepper motor operating at 115 VAC.  
28 In one embodiment, motor 140 is a 90-degree stepper motor operating at 12 VDC. In one  
29 embodiment, motor 140 is unidirectional, NEMA 4 enclosure rated at 69VA total power, 80 lb.-  
30 in. torque and 2 sec./90-degree rotation. Motor 140 actuates selector valve 150 when operatively  
31 coupled to power supply 110 via motor relay 120.

1        Seepage chamber 160 is operatively coupled to selector valve 150. Seepage chamber 160  
2 receives seepage (i.e., water that is pushed through the interstitial spaces of marine or aquatic  
3 sediments by a hydraulic gradient formed between groundwater and offshore water levels) from  
4 sediment. Seepage chamber 160 receives seepage through an open end and outputs seepage  
5 through an outlet. In one embodiment, seepage chamber 160 is a semi-enclosed chamber (e.g., a  
6 drum cut in half having a closed end and an open end with an outlet drilled in the closed end,  
7 which is opposite of the open end). In one embodiment, seepage chamber 160 is a funnel. In  
8 one embodiment, seepage chamber 160 is a 9-inch bottom section of an 18-inch diameter SDPE  
9 container with a 2-inch threaded plug as an outlet. In one embodiment, seepage chamber 160  
10 further comprises an outlet conduit operatively coupled to the outlet. The outlet conduit directs  
11 seepage to components such as selector valve 150. In one embodiment, the outlet conduit  
12 comprises ½-inch TEFLON® compression fitting. Seepage chamber 160 inputs seepage to  
13 selector valve 150.

14       Selector valve 150 is operatively coupled to motor 140, seepage chamber 160 and sample  
15 containers 170. Selector valve 150 receives seepage from seepage chamber 160. Selector valve  
16 150 actuates via motor 140 in accordance with a sampling schedule. Selector valve 150 includes  
17 an inlet port and at least two outlet ports. In accordance with the present invention, selector  
18 valve 150 operatively couples the inlet port to one of the at least two outlet ports in accordance  
19 with a sampling schedule. In one embodiment, selector valve 150 comprises a six-way selector  
20 valve having one inlet port and six outlet ports. In one embodiment, selector valve 150  
21 comprises a four-way selector valve having one inlet port and four outlet ports. In one  
22 embodiment, selector valve 150 comprises two four-way selector valves. In one embodiment,  
23 selector valve 150 is a ½-inch four-way selector valve comprising 316 stainless steel bar stock  
24 with TEFLON® sleeve around rotor. In one embodiment, the inlet port of selector valve 150 is  
25 operatively coupled to the outlet of the seepage chamber 160. In one embodiment, the inlet port  
26 of selector valve 150 is operatively coupled to the outlet of the seepage chamber 160 via an  
27 outlet conduit. In one embodiment, motor 140 rotates selector valve 150 90 degrees per sample  
28 time. Selector valve 150 inputs seepage to one of the plurality of sample containers 170.

29       Sample containers 170 are operatively coupled to selector valve 150. Sample containers  
30 170 are vessels for containing seepage samples. Those skilled in the art shall recognize that  
31 TSM 100 can comprise multiple sample containers 170 without departing from the scope or

1 spirit from the present invention. In one embodiment, sample containers 170 comprise  
2 TEFLON® gas sampling bags. Sample containers 170 receive seepage from seepage chamber  
3 160 via selector valve 150. In one embodiment, a separate sample container 170 is operatively  
4 coupled to each outlet port of selector valve 150. In one embodiment, separate sample  
5 containers 170 are operatively coupled to selected outlet ports of selector valve 150.

6 An exemplary operation of TSM 100 is now described. Computer 190 downloads a  
7 sampling schedule to controller 130 of TSM 100. TSM 100 is positioned in sediment. Seepage  
8 enters seepage chamber 160. Controller 130 activates motor relay 120 in accordance with the  
9 sampling schedule. Motor relay 120 provides electrical coupling between power supply 110 and  
10 motor 140 when activated (e.g., activated for 2 seconds at 1400 HRS). When electrically  
11 coupled to power supply 110, motor 140 actuates selector valve 150, which selects an outlet port  
12 or, in one embodiment, a next outlet port. Seepage chamber 160 inputs seepage to an inlet port  
13 of selector valve 150. Selector valve 150 inputs seepage to one of a plurality of sample  
14 containers 170 via a selected outlet port. Controller 130 re-activates motor relay 120 in  
15 accordance with the sampling schedule to provide a desired number of samples.

16 FIGURE 3 is an exemplary representation of an embodiment of the present invention. As  
17 shown in FIG. 3, tidal seepage meter 300 includes seepage chamber 360 and main housing 380.  
18 TSM 300 is positioned beneath water body 302 and partially embedded in sediment 304. In an  
19 exemplary implementation, TSM 300 is positioned with seepage chamber 360 substantially  
20 embedded in sediment 304 so that sediment surface 306 is substantially flush with the top of  
21 seepage chamber 360. In an exemplary implementation, one side of TSM 300 is slightly higher  
22 than other sides of TSM 300 with respect to sediment surface 306 so that seepage flows through  
23 an outlet of seepage chamber 360.

24 FIGURE 4 is an exemplary embodiment of the present invention. As shown in FIG. 4,  
25 tidal seepage meter 400 includes seepage chamber 460, which is analogous to seepage chambers  
26 160 and 360 of FIGS. 1 and 3, respectively, and main housing 480, which is analogous to main  
27 housing 380 of FIG. 3. TSM 400 of FIG. 4 is substantially similar to TSM 100 of FIG. 1, and  
28 thus, identical components are not described in detail hereinagain. Seepage chamber 460 further  
29 includes outlet conduit 462. Main housing 480 includes power and controller housing 482,  
30 stepper motor 440, selector valve 450 and sampling containers 470. Power and controller

1 housing further includes power 410, relay 420 and controller 430. Selector valve 450 further  
2 comprises outlet ports 472.

3 Seepage chamber 460 is operatively coupled to selector valve 450 via outlet conduit 462.  
4 Seepage (represented by vertical and horizontal arrows in FIG. 4) enters seepage chamber 460  
5 from open end 464 and travels to selector valve 450 via outlet conduit 462. Controller 430 is  
6 capable of receiving a sampling schedule. Controller 430 is operatively coupled to motor relay  
7 420 and inputs control signals to motor relay 420 in accordance with the sampling schedule.  
8 Relay 420 operatively couples power 410 and stepper motor 440 when activated by control  
9 signals from controller 430. Stepper motor 440 actuates selector valve 450 when coupled to  
10 power 410 via relay 420. Selector valve 450 is operatively coupled to seepage chamber 460 (via  
11 outlet conduit 462), stepper motor 440 and sample containers 470 (via outlet ports 472). Selector  
12 valve 450 receives seepage from seepage chamber 460 via outlet conduit 462. Selector valve  
13 450 directs seepage to one of the sample containers 470 via outlet ports 472. Motor 440 actuates  
14 selector valve 450 in accordance with a sampling schedule, which selects one of the plurality of  
15 sample containers 470. Although FIG. 4 shows only two sample containers, those skilled in the  
16 art shall recognize that TSM 400 can comprise more than two sample containers (e.g., six sample  
17 containers) without departing from the scope or spirit of the present invention.

18 FIGURE 5 is an exemplary selector valve and sample container embodiment of the  
19 present invention. The exemplary selector valve and sample container embodiment ("six-sample  
20 embodiment") 500 includes two four-way selector valves and six sample containers. As shown  
21 in FIG. 5, six-sample embodiment 500 includes selector valves 550 and 552 and sample  
22 containers 570. Inlet ports 556 of selector valves 550 and 552 receive seepage from a seepage  
23 chamber via outlet conduits 562, which are analogous to outlet conduit 462 of FIG. 4. Selector  
24 valves 550 and 552 input seepage to sample containers 570 via outlet ports 572. Stoppers 558  
25 cover selected outlet ports of selector valves 550 and 552.

26 Six-sample embodiment 500 operates in the following manner. Initially, covered outlet  
27 ports of selector valves 550 and 552 are selected. Thus, seepage cannot flow out of selector  
28 valves 550 and 552. When a first sampling time occurs in accordance with a sampling schedule,  
29 a motor actuates selector valve 550, which rotates selector valve 550 90 degrees clockwise.  
30 Thus, seepage flows from outlet conduit 562 to sample container 570 located at the 6 o'clock  
31 position of selector valve 550 via inlet port 556. At a second sampling time, the motor actuates

1 selector valve 550, which rotates selector valve 550 90 degrees clockwise. Thus, seepage flows  
2 from outlet conduit 562 to sample container 570 located at the 9 o'clock position of selector  
3 valve 550 via inlet port 556. At a third sampling time, the motor actuates selector valve 550,  
4 which rotates selector valve 550 90 degrees clockwise. Thus, seepage flows from outlet conduit  
5 562 to sample container 570 located at the 12 o'clock position of selector valve 550 via inlet port  
6 556. At a fourth sampling time, the motor actuates selector valve 550, which rotates selector valve  
7 550 90 degrees clockwise, and actuates selector valve 552, which rotates selector valve  
8 552 90 degrees clockwise. Thus, seepage is prevented from flowing out of selector valve 550  
9 due to stopper 558; and seepage flows from outlet conduit 562 to sample container 570 located at  
10 the 12 o'clock position of selector valve 552 via inlet port 556. At a fifth sampling time, the  
11 motor actuates selector valve 552, which rotates selector valve 552 90 degrees clockwise. Thus,  
12 seepage flows from outlet conduit 562 to sample container 570 located at the 3 o'clock position  
13 of selector valve 552 via inlet port 556. At a sixth sampling time, the motor actuates selector  
14 valve 552, which rotates selector valve 552 90 degrees clockwise. Thus, seepage flows from  
15 outlet conduit 562 to sample container 570 located at the 6 o'clock position of selector valve 552  
16 via inlet port 556. After the sixth sampling time, the motor actuates selector valve 552, which  
17 rotates selector valve 552 90 degrees clockwise. Thus, seepage is substantially prevented from  
18 flowing in outlet conduit 562 due to stopper 558 located at the 9 o'clock position of selector  
19 valve 552.

20 FIGURE 6 is a flowchart of an exemplary method of implementing an embodiment of the  
21 present invention. Certain details and features have been left out of flowchart 600 of FIG. 6 that  
22 are apparent to a person of ordinary skill in the art. For example, a step may consist of one or  
23 more sub-steps or may involve specialized equipment or materials, as known in the art. While  
24 STEPS 610 through 670 shown in flowchart 600 are sufficient to describe one embodiment of  
25 the present invention, other embodiments of the invention may utilize steps different from those  
26 shown in flowchart 600.

27 Referring to FIG. 6, at STEP 610 in flowchart 600, the method prepares the tidal seepage  
28 meter. In one embodiment, the method prepares the tidal seepage meter by cleaning all  
29 plumbing. After STEP 610, the method of flowchart 600 of FIG. 6 proceeds to STEP 620.

30 At STEP 620 in flowchart 600, the method transfers a sampling schedule to a controller  
31 of the TSM. In one embodiment, the method downloads a sampling schedule to a controller of

1 the TSM from a computer. After STEP 620, the method of flowchart 600 of FIG. 6 proceeds to  
2 STEP 630.

3 At STEP 630 in flowchart 600, the method positions the TSM in sediment. In one  
4 embodiment, the method positions the TSM in the sediment by embedding a seepage chamber of  
5 the TSM substantially in the sediment so that the sediment surface is substantially flush with the  
6 top of the seepage chamber. After STEP 630, the method of flowchart 600 of FIG. 6 proceeds to  
7 STEP 640.

8 At STEP 640 in flowchart 600, the method equilibrates the tidal seepage meter. In one  
9 embodiment, the method equilibrates the TSM by waiting a predetermined amount of time to  
10 allow seepage flow conditions to return to normal. After STEP 640, the method of flowchart 600  
11 of FIG. 6 proceeds to STEP 650.

12 At STEP 650 in flowchart 600, the method activates the tidal seepage meter. In one  
13 embodiment, the method activates the TSM by moving a magnet mounted to the exterior of a  
14 main housing of the TSM from an "off" position to an "on" position, which activates a magnetic  
15 switch in the main housing. After STEP 650, the method of flowchart 600 of FIG. 6 proceeds to  
16 STEP 660.

17 At STEP 660 in flowchart 600, the method samples seepage in accordance with the  
18 sampling schedule. In one embodiment, the method sends control signals to a motor relay to  
19 operatively couple a power supply and a motor, which actuates a selector valve. The selector  
20 valve operatively couples a seepage chamber to a selected one of a plurality of sample  
21 containers. Selector valve actuation continues in accordance with the sampling schedule. After  
22 STEP 660, the method of flowchart 600 of FIG. 6 proceeds to STEP 670.

23 At STEP 670 in flowchart 600, the method retrieves TSM samples. In one embodiment,  
24 the method obtains TSM samples from sample containers after the TSM is retrieved.

25 FIGURE 7 is a flowchart of an exemplary method of implementing an embodiment of the  
26 present invention. Certain details and features have been left out of flowchart 760 of FIG. 7 that  
27 are apparent to a person of ordinary skill in the art. For example, a step may consist of one or  
28 more sub-steps or may involve specialized equipment or materials, as known in the art. While  
29 STEPS 762 through 766 shown in flowchart 760 are sufficient to describe one embodiment of  
30 the present invention, other embodiments of the invention may utilize steps different from those  
31 shown in flowchart 760.

1           Flowchart 760 is an exemplary implementation of STEP 660 of flowchart 600 of FIG. 6.  
2 Referring to FIG. 7, at decision STEP 762 in flowchart 760, the method determines whether a  
3 scheduled rotation time has occurred. If so, the method proceeds to STEP 764 whereat the  
4 method rotates a selector valve. If not, the method returns to STEP 762. After STEP 764, the  
5 method proceeds to decision STEP 766 whereat the method determines whether sampling is  
6 completed. If sampling is not completed, the method returns to decision STEP 762. If sampling  
7 is completed, the method proceeds to STEP 670 of flowchart 600 of FIG. 6. In one embodiment  
8 of STEP 766, the method rotates to a plugged port if sampling is completed and proceeds to  
9 STEP 670 of flowchart 600 of FIG. 6.

10          From the above description of the invention, it is manifest that various techniques can be  
11 used for implementing the concepts of the present invention without departing from its scope.  
12 Moreover, while the invention has been described with specific reference to certain  
13 embodiments, a person of ordinary skill in the art would recognize that changes can be made in  
14 form and detail without departing from the spirit and the scope of the invention. The described  
15 embodiments are to be considered in all respects as illustrative and not restrictive. It should also  
16 be understood that the invention is not limited to the particular embodiments described herein,  
17 but is capable of many rearrangements, modifications, and substitutions without departing from  
18 the scope of the invention.